BODY FLUIDS

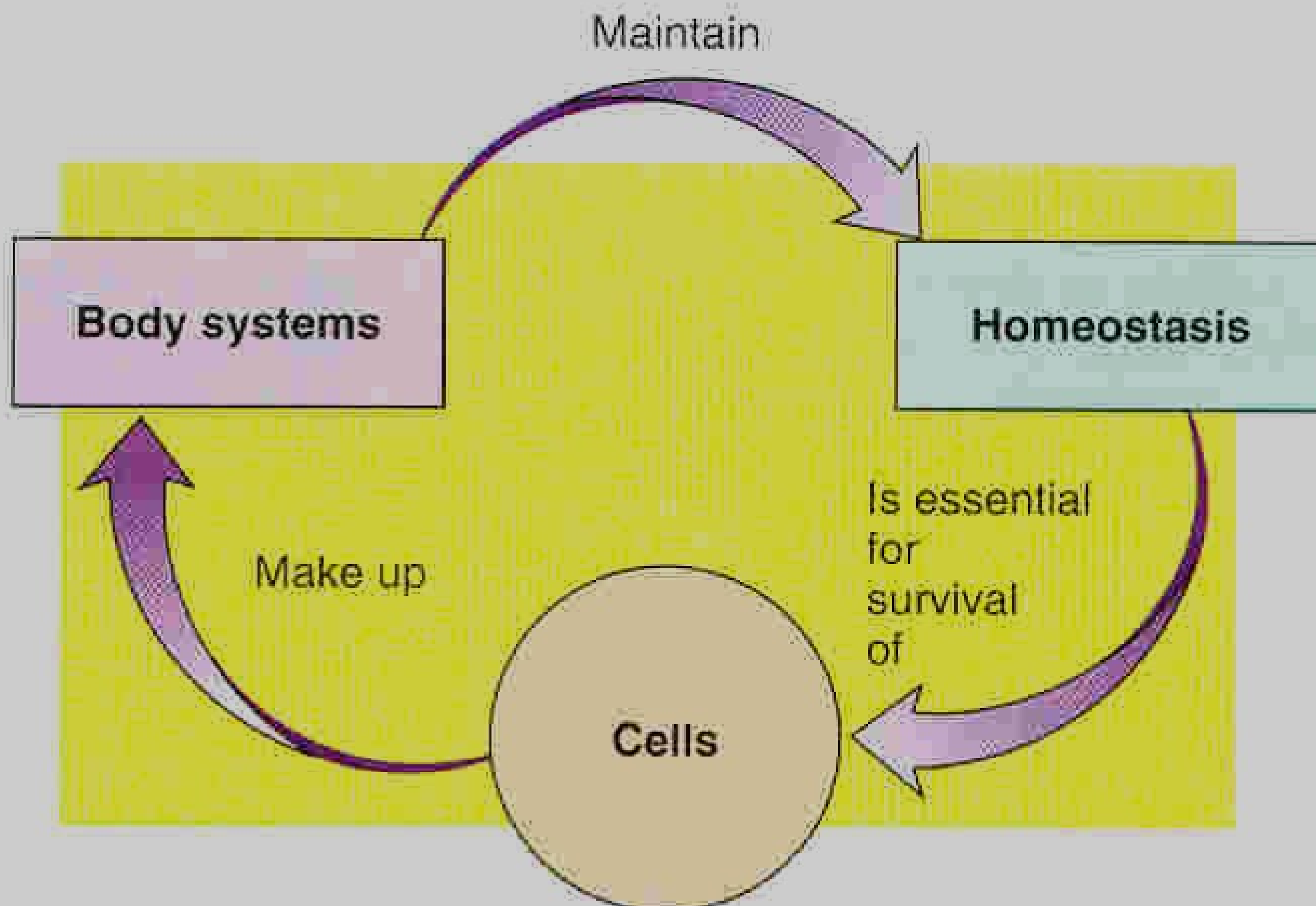
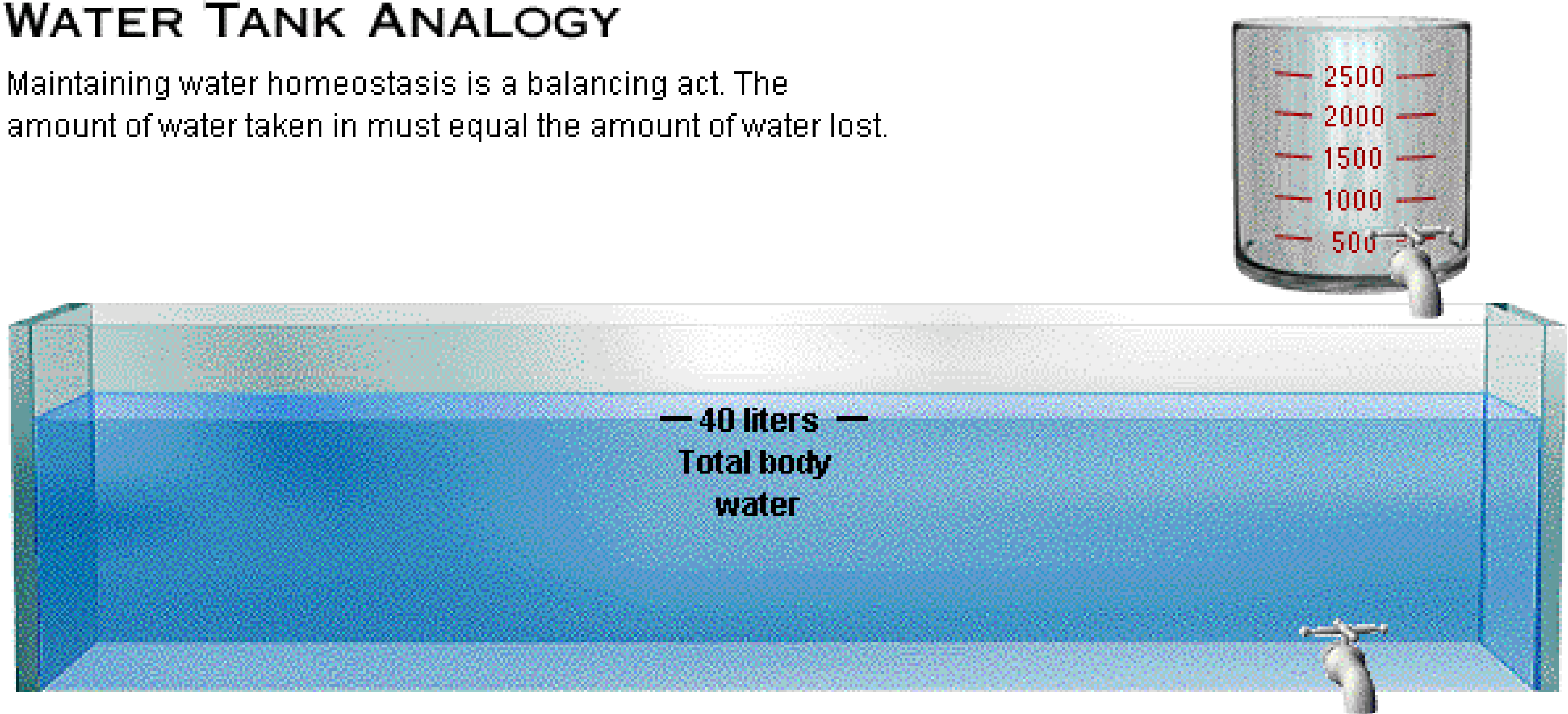

Maintain
Body systems
Homeostasis
Is essential for survival of
Make up
Cells

FIGURE 1-3

Water Tank Analogy

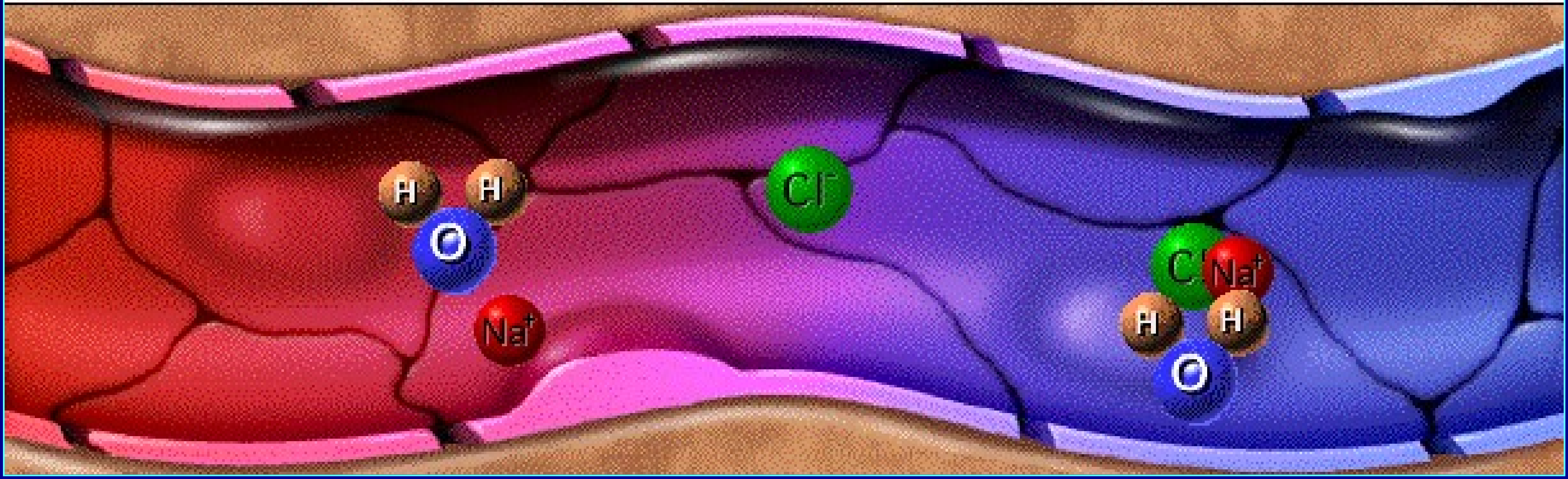
Maintaining water homeostasis is a balancing act. The amount of water taken in must equal the amount of water lost.



Water Intake	Water Output
▪ Food and drink: 2300 mL ▪ Cell metabolism: 200 mL	▪ Kidneys: 1500 mL ▪ Skin: 600 mL ▪ Lungs: 300 mL ▪ GI tract: 100 mL
▪ Total: 2500 mL	**▪ Total: 2500 mL**

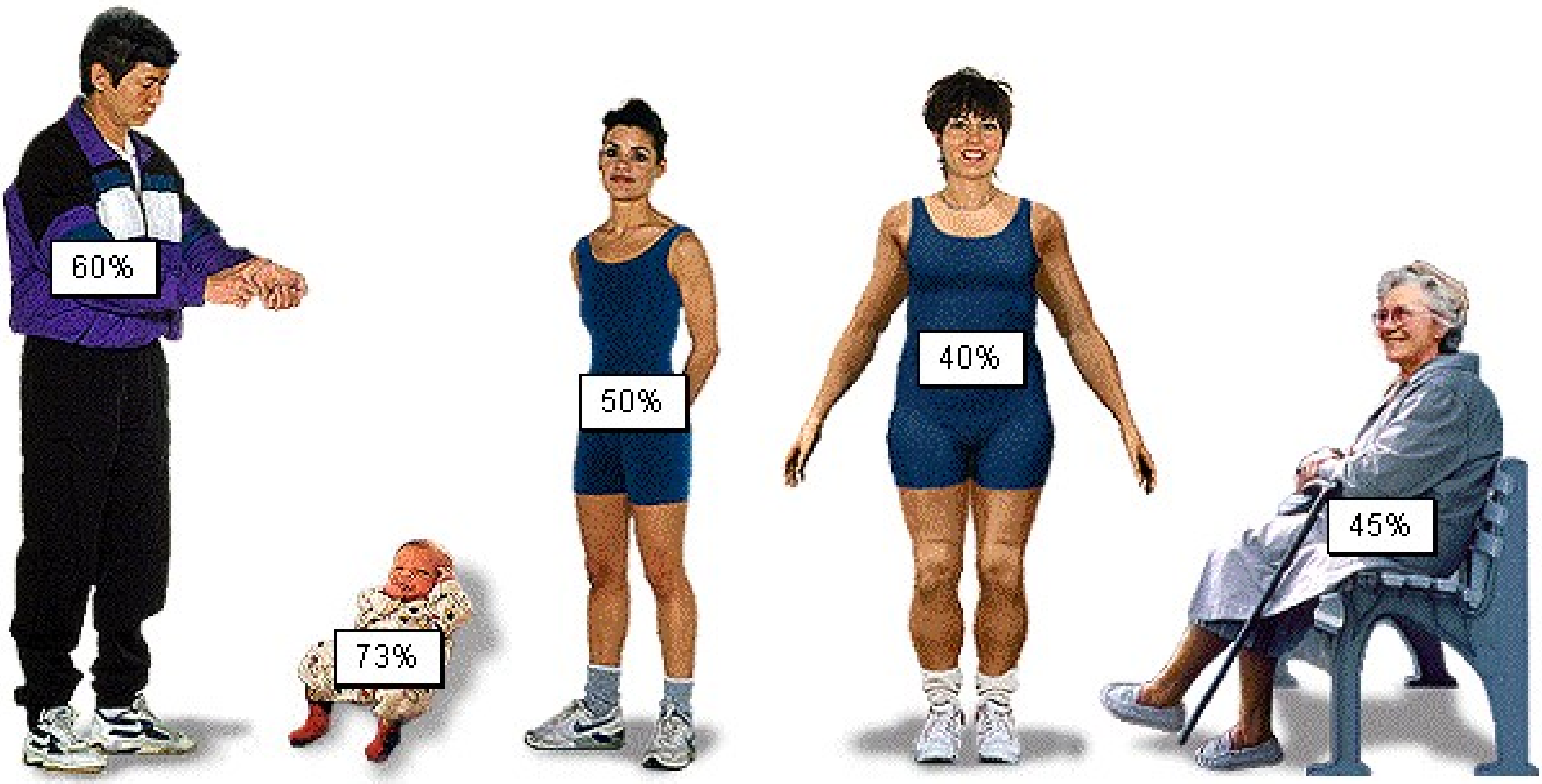
Roles of Water

- Temperature regulation
- Protective cushion
- Lubricant
- Reactant
- Solvent
- Transport



Percentage of Water in the Body

Click each of the people below to determine the approximate percentage of water in their bodies.



In the average 70-kilogram adult human, the total body water is about 60 per cent of the body weight, or about 42 liters.

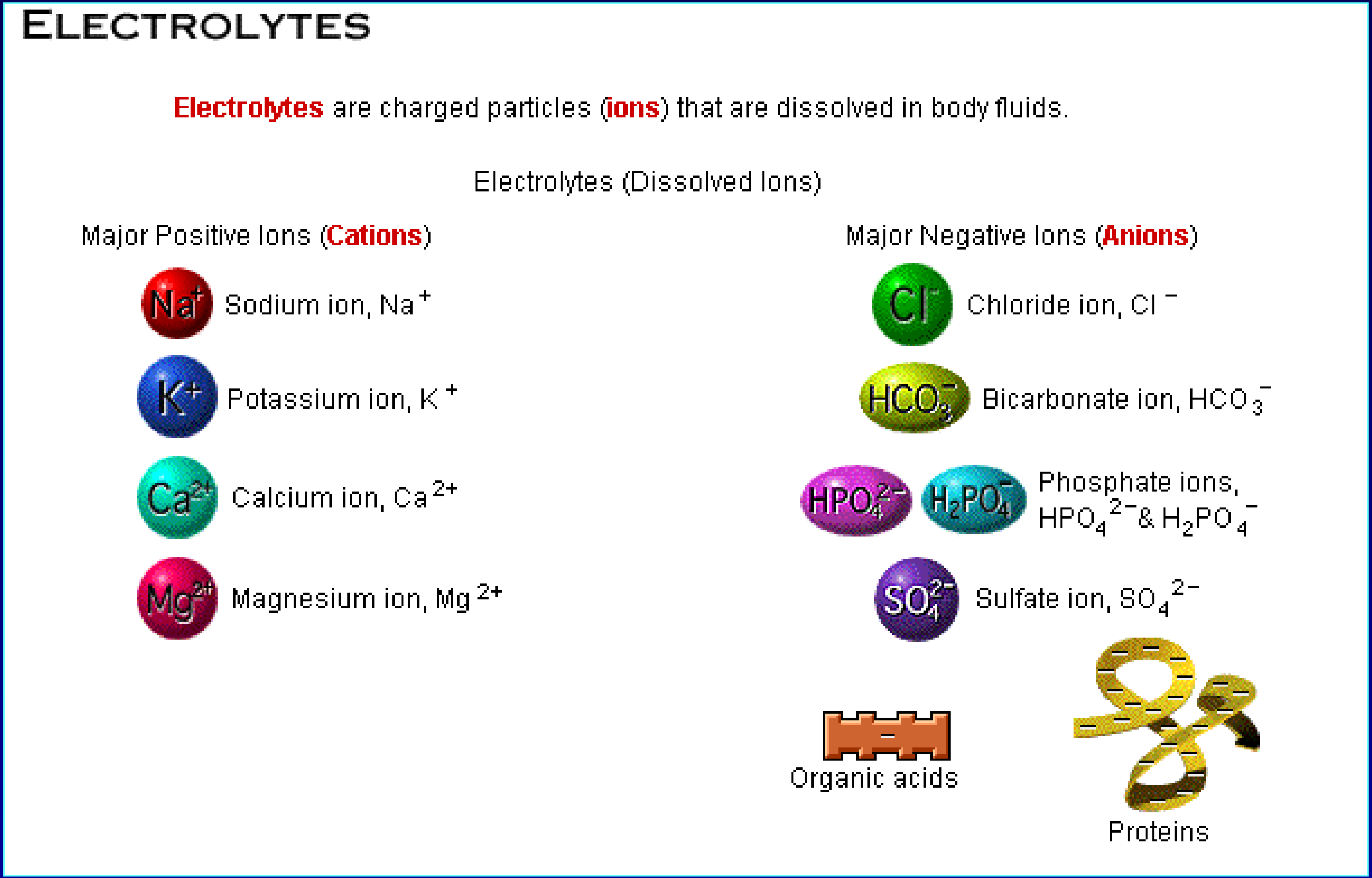
This percentage can change, depending on age, gender, and degree of obesity.

FACTORS AFFECTING

Total Body Water

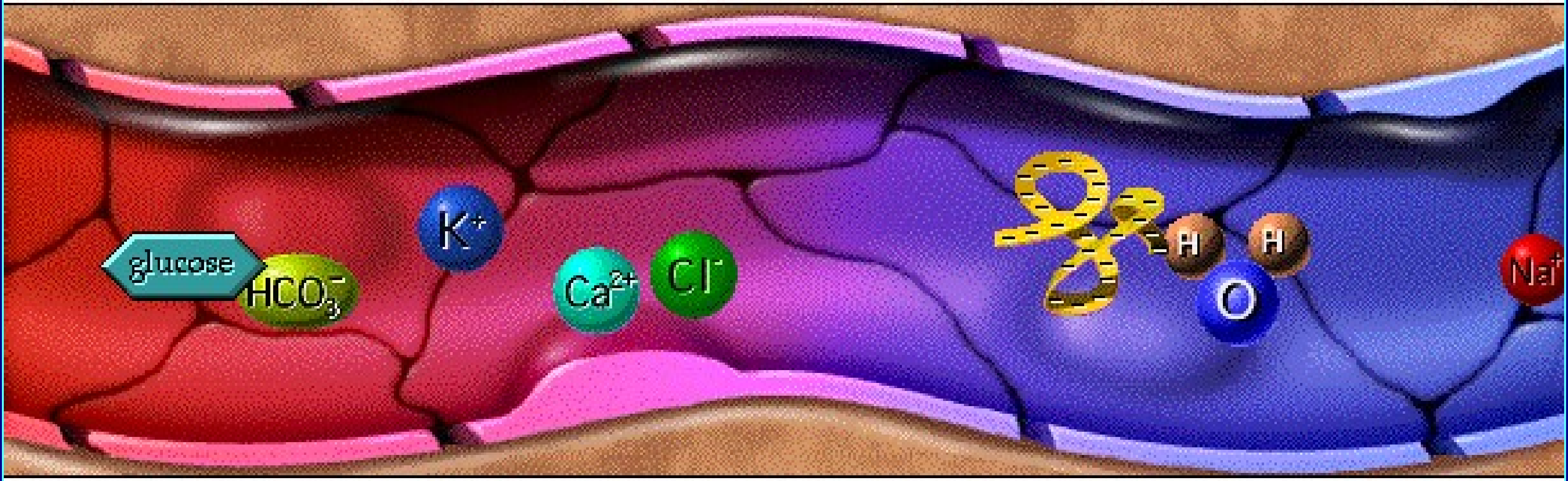
- varies depending on body fat:
  - infant: 73%
  - male adult: 60%
  - female adult: 40-50%
  - effects of obesity ↓
  - Old age 45%

COMPOSITION OF BODY FLUIDS



Composition of Body Fluids

You are looking at **plasma**, a typical body fluid.



COMPOSITION OF BODY FLUIDS

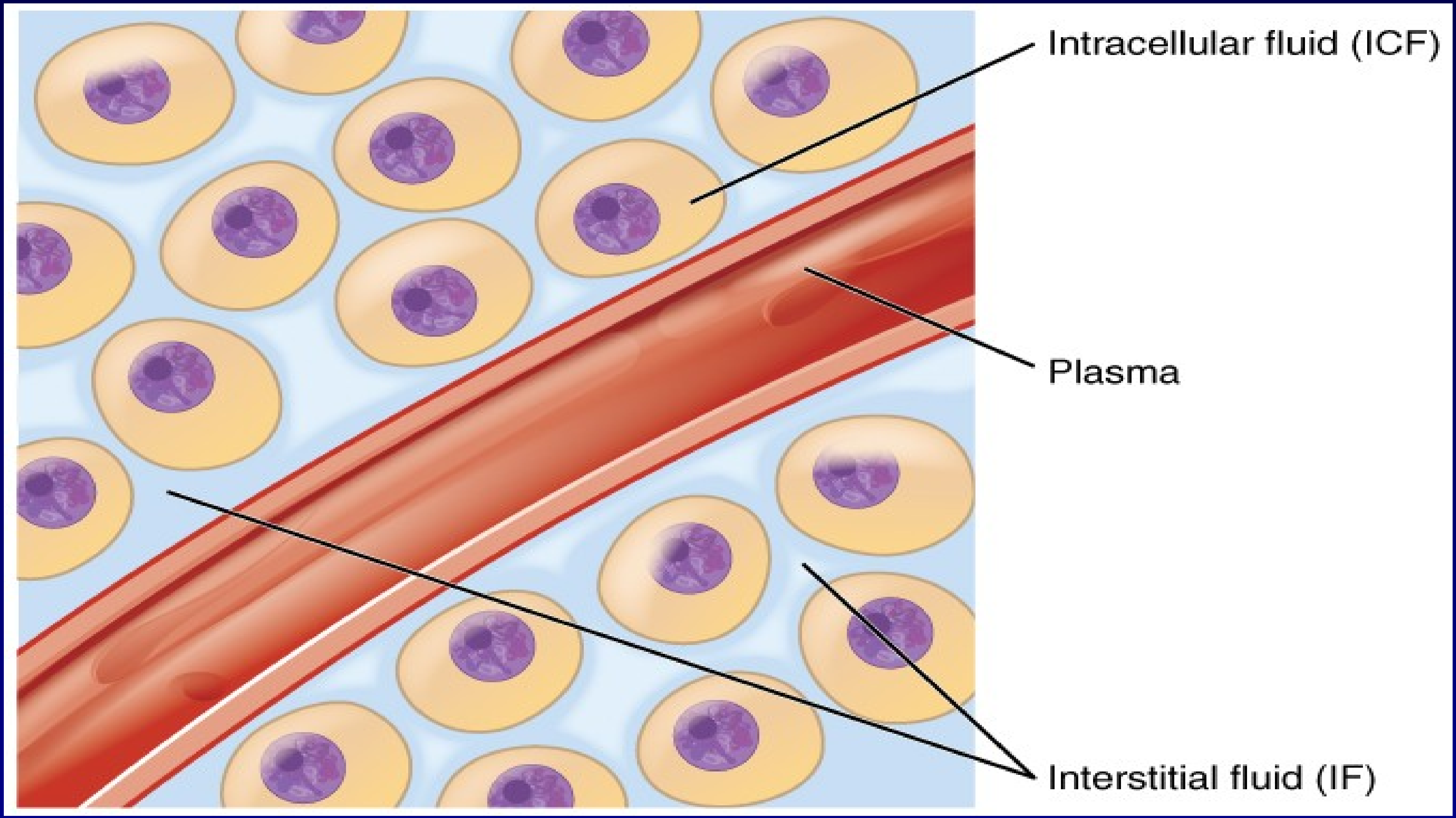
CATIONS (mmol/l)	Plasma	Interstitial	Intracellular
Na	142	139	14
K	4.2	4.0	140
Ca	1.3	1.2	0
Mg	0.8	0.7	20
ANIONS (mmol/l)			
Cl	108	108	4.0
HCO3	24.0	28.3	10
Protein	1.2	0.2	4.0
HPO4	2.0	2.0	11

IMPORTANCE

- **Maintaining ECF volume is critical to maintaining blood pressure**
- **ECF osmolarity is of primary importance in long-term regulation of ECF volume**
  - **ECF osmolarity maintained mainly by NaCl balance:**
    - **intake: 10.5g/d**

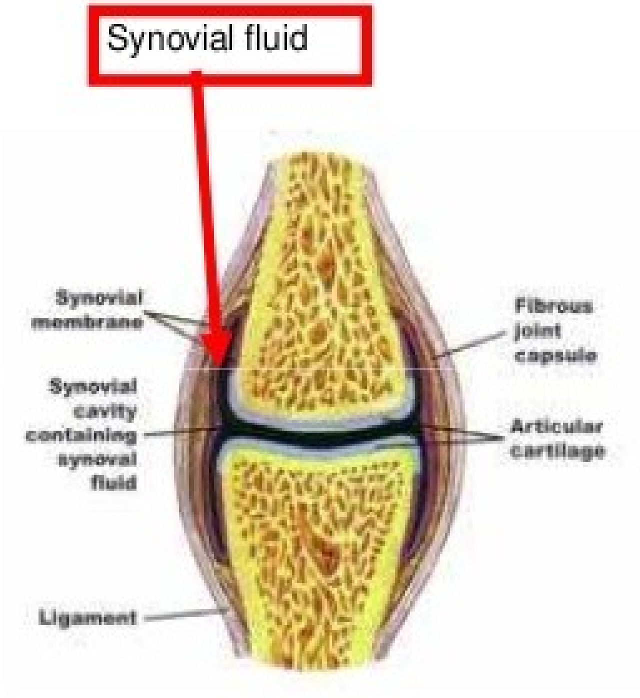
FLUID COMPARTMENTS

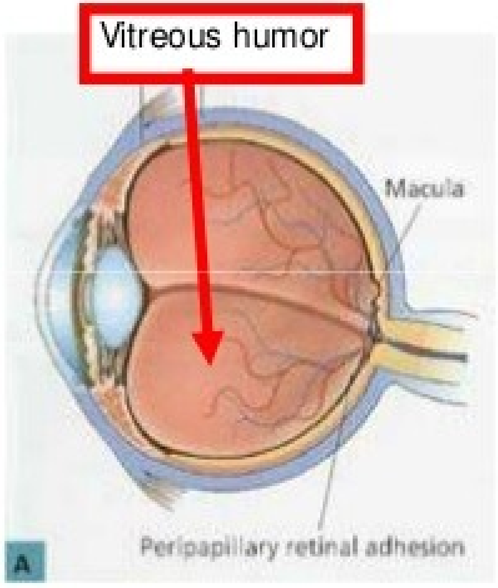
- EXTRA CELLUAR FLUID
  - PLASMA
  - INTERSTITIAL FLUID
  - TRANSCELLULAR FLUID
    - CSF
    - Intra ocular
    - Pleural
    - Peritoneal
    - Synovial
    - Digestive Secretions
- INTRA CELLULAR FLUID

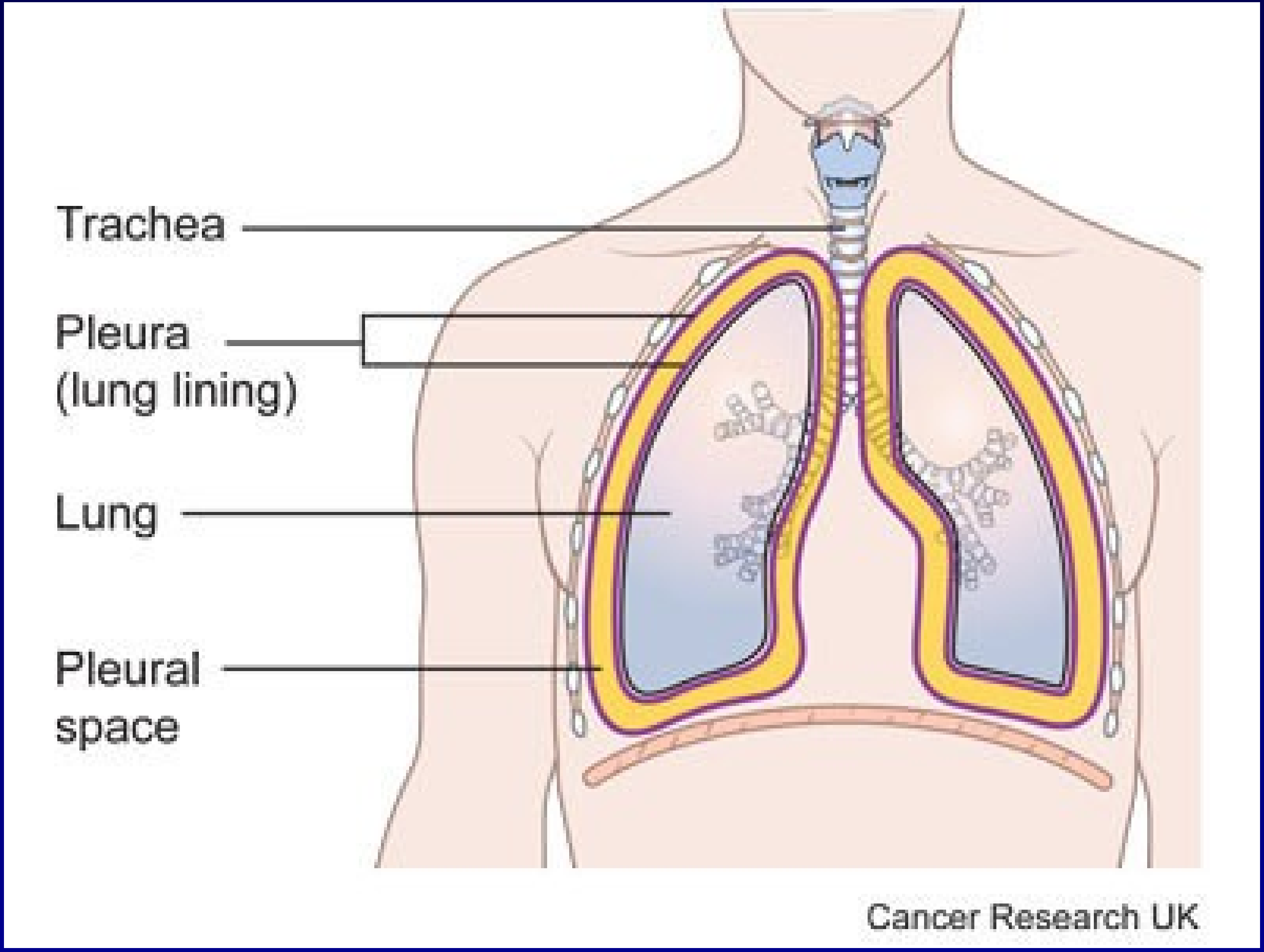


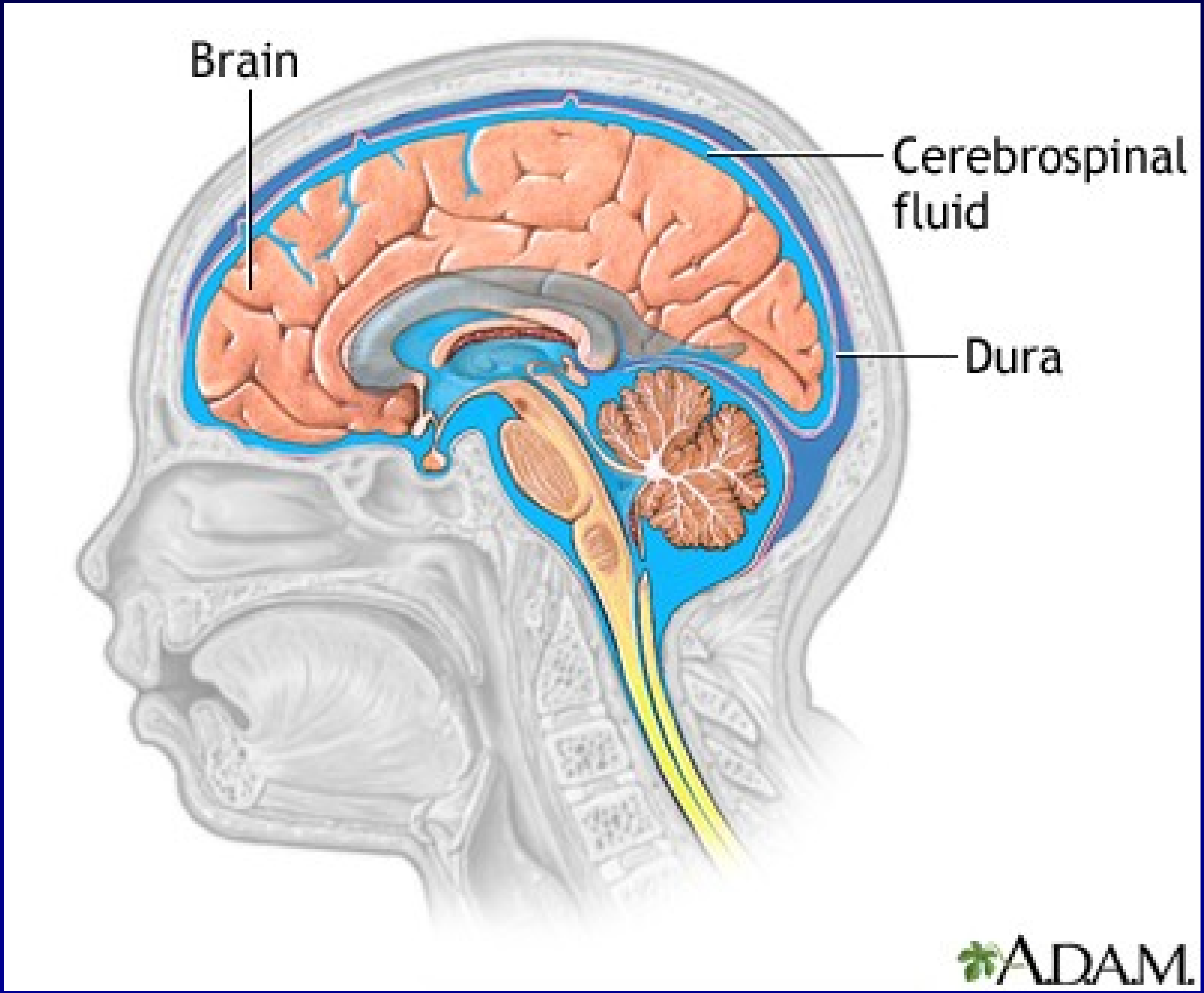
Interstitial fluid or **tissue fluid** is a solution that bathes and surrounds the tissue cells of multicellular animals. The interstitial fluid is found in the interstices- the spaces between cells (also known as the tissue spaces).

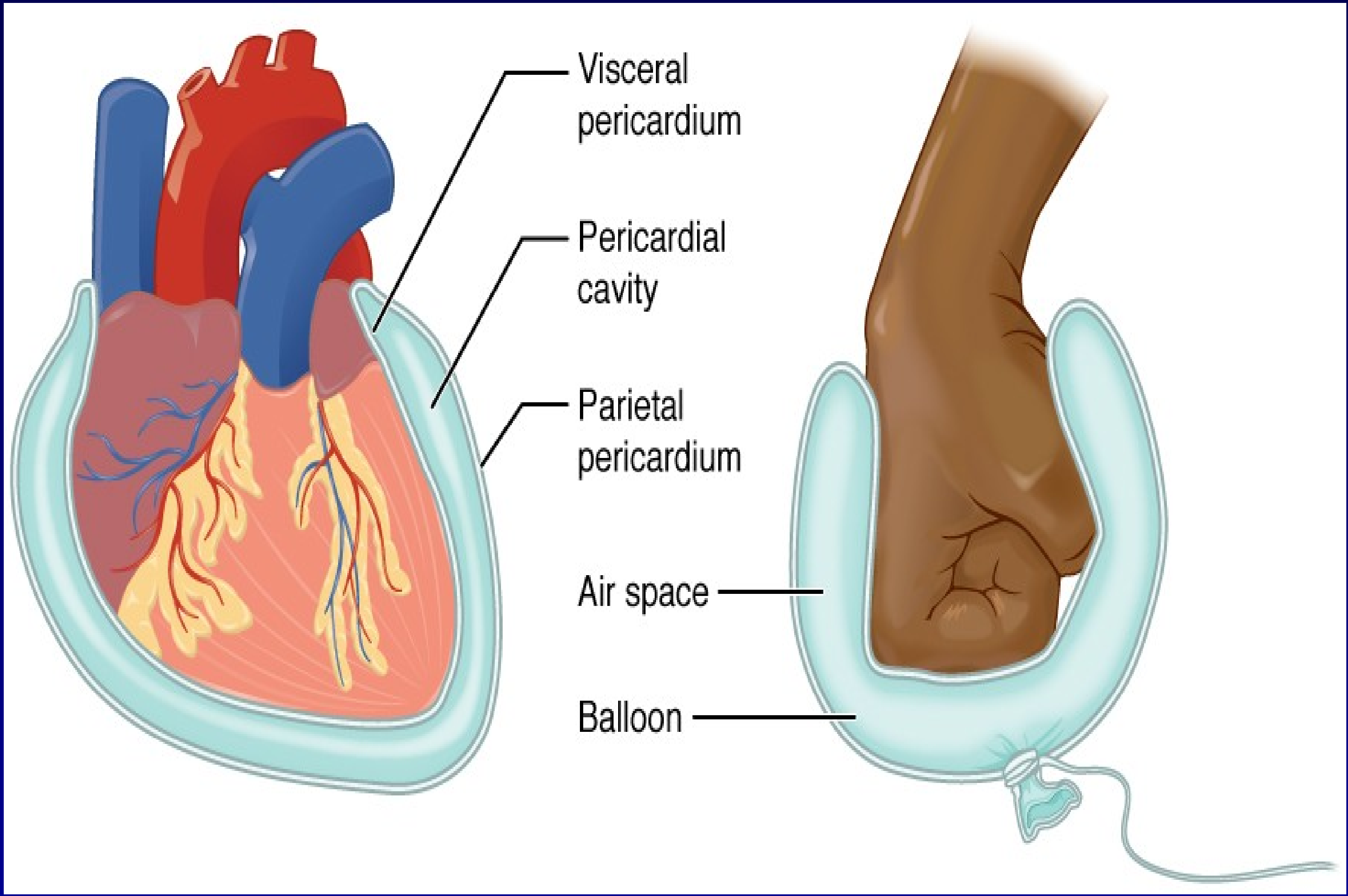
Transcellular fluid






Trachea
Pleura
(lung lining)
Lung
Pleural
space
Cancer Research UK


Brain
Cerebrospinal fluid
Dura
A.D.A.M.


Visceral pericardium
Pericardial cavity
Parietal pericardium
Air space
Balloon

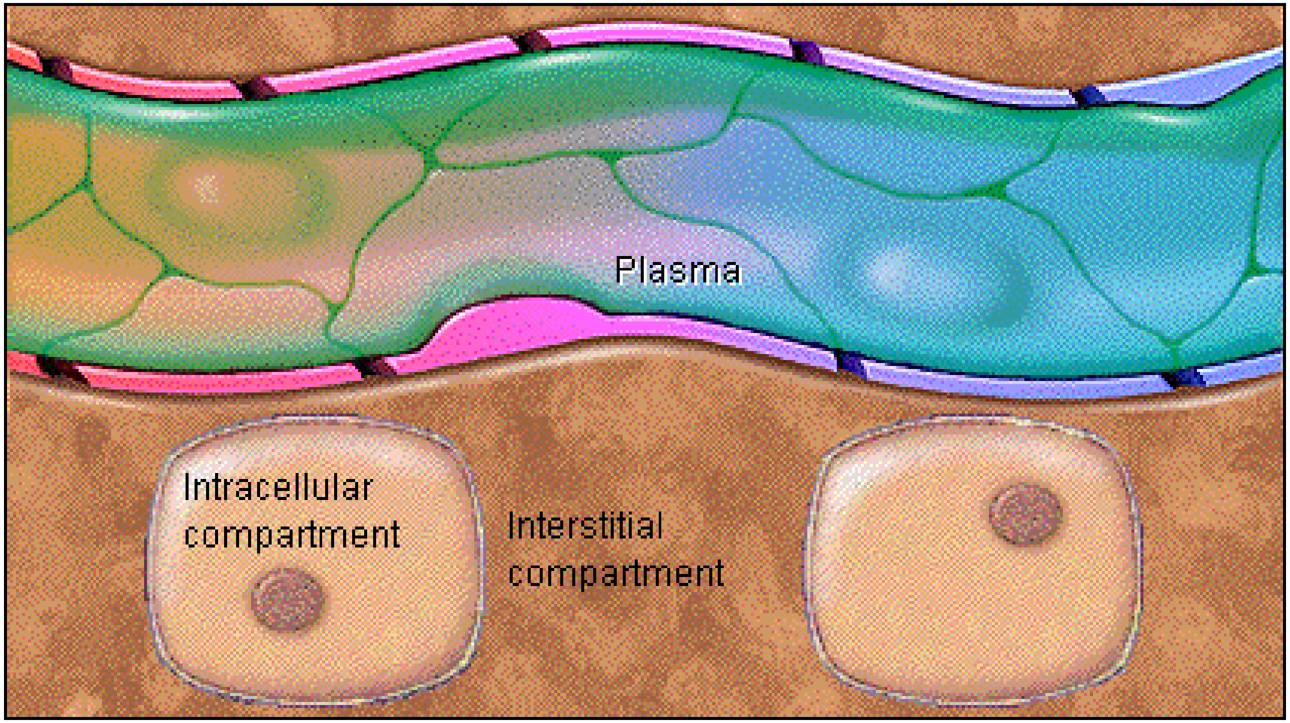
Fluid Compartments

The three major fluid compartments:

- **Intracellular fluid** (**ICF**) is the fluid within cells, also known as cytosol.
- **Extracellular fluid** (**ECF**) is the fluid found outside of cells.

There are two major kinds of extracellular fluid:

- **Interstitial fluid** is the fluid surrounding the cells.
- **Plasma** is the fluid component of blood.



Ionic Composition of Plasma and Interstitial Fluid Is Similar

Because the plasma and interstitial fluid are separated only by highly permeable capillary membranes, their ionic composition is similar.

The most important difference between these two compartments is the higher concentration of protein in the plasma; because the capillaries have a low permeability to the plasma proteins, only small amounts of proteins are leaked into the

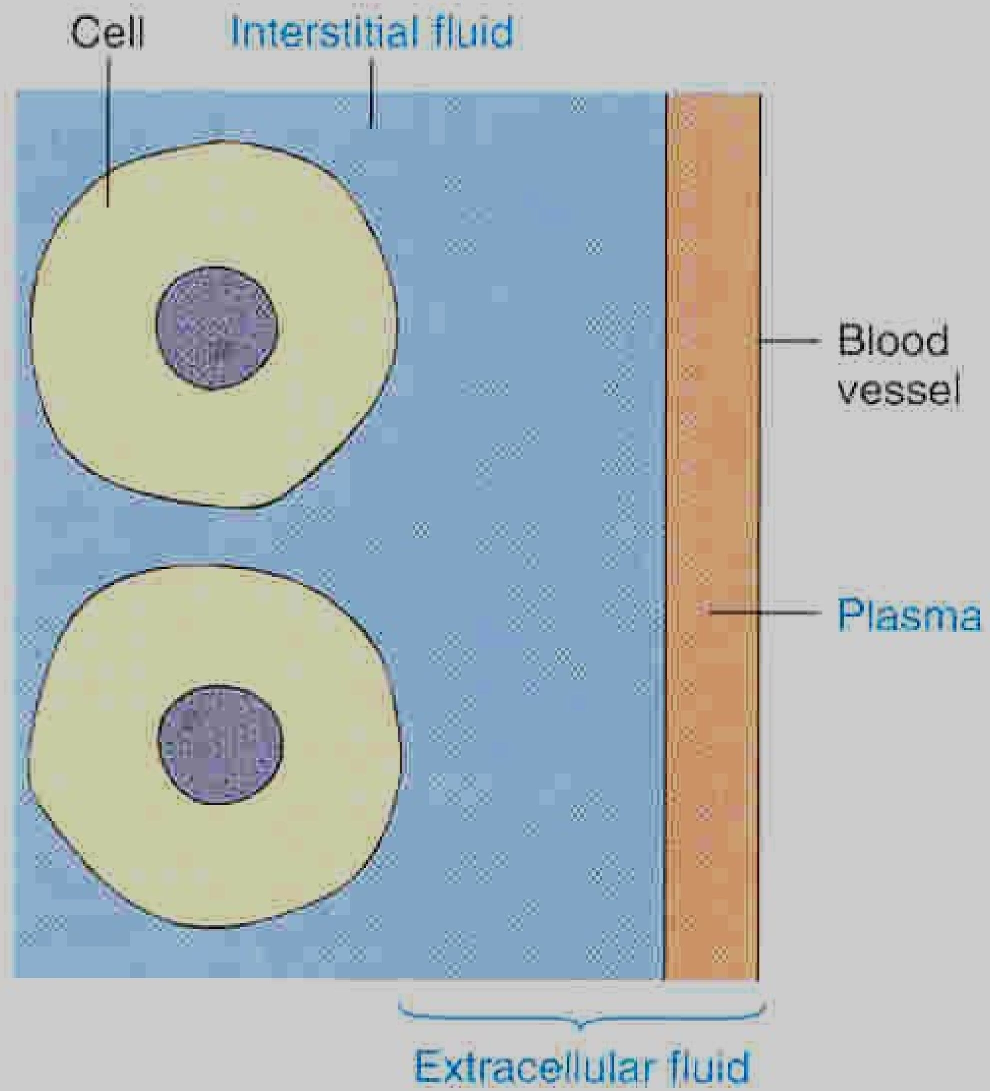

Cell
Interstitial fluid
Blood
vessel
Plasma
Extracellular fluid

FIGURE 1-2

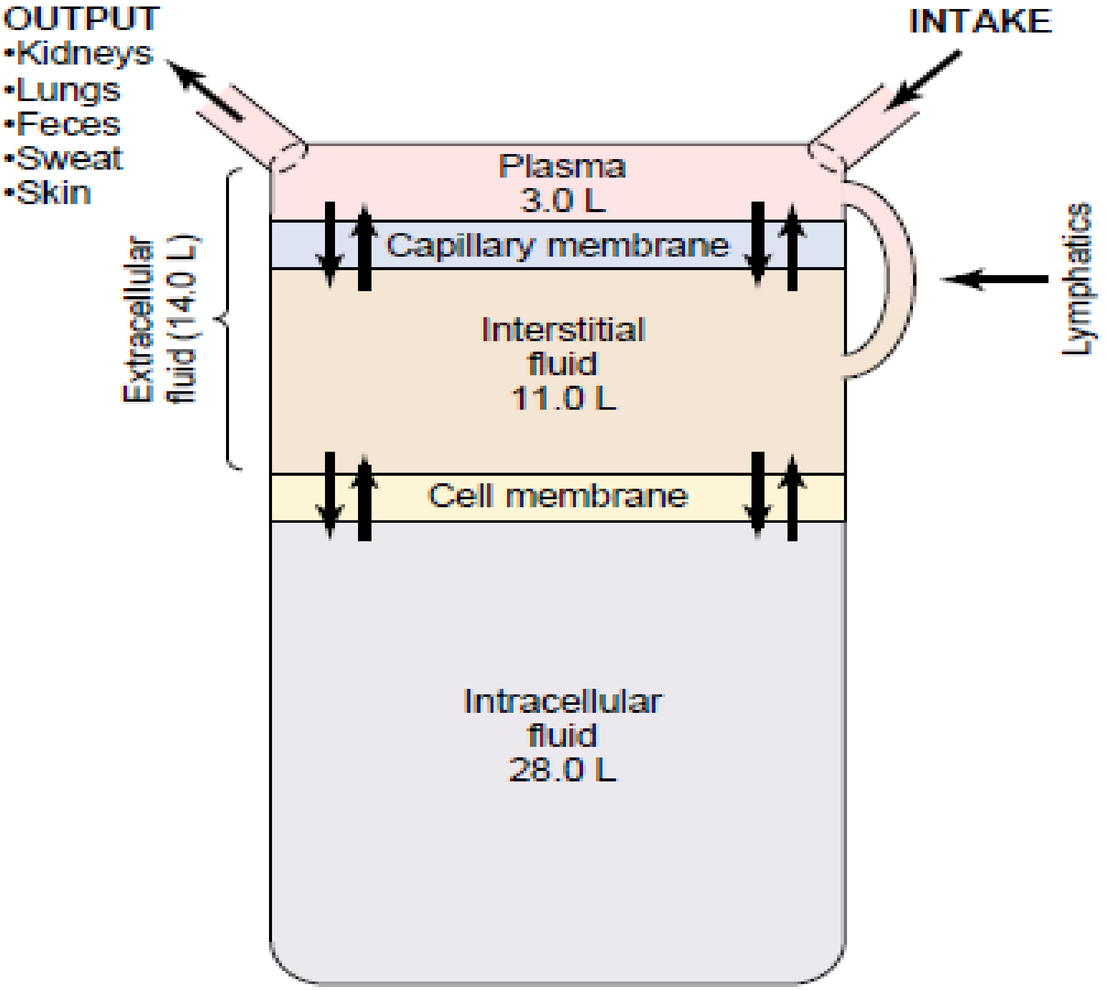


Figure 25–1

Summary of body fluid regulation, including the major body fluid compartments and the membranes that separate these compartments. The values shown are for an average 70-kilogram person.

VOLUME OF BODY FLUIDS IN 70 kg MAN

TOTAL VOLUME

42 L

INTRA CELLUAR FLUID

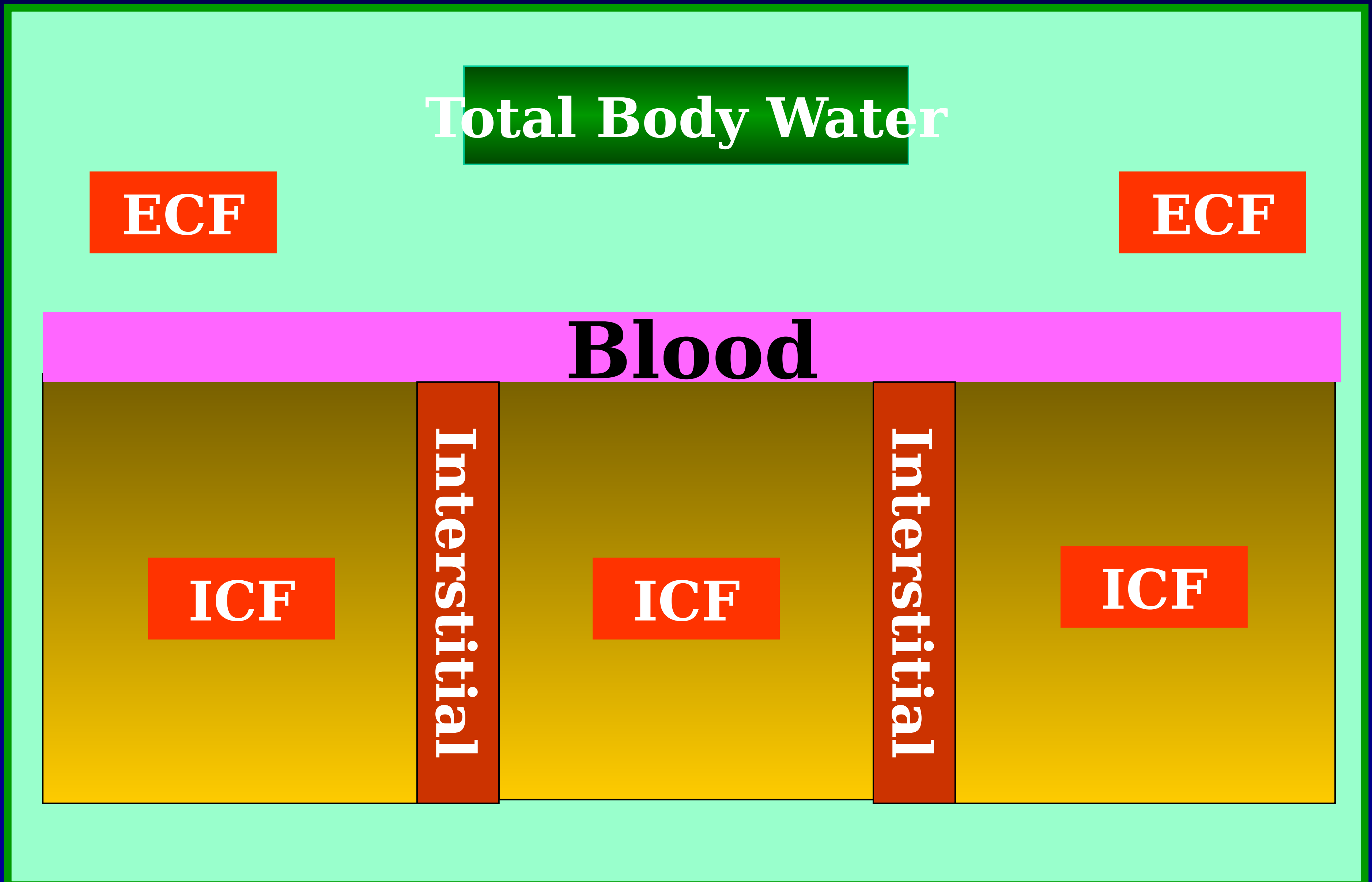
28 L(ROUGHLY 2/3 OF TBW)

EXTRA CELLULAR FLUID

14 L(ROUGHLY 1/3 OF TBW)

PLASMA

3 L (ROUGHLY ¼ OF ECF)


Total Body Water
ECF
ECF
Blood
Interstitial
Interstitial
ICF
ICF
ICF

TOTAL BODY WATER(TBW)

- **60% OF THE BODY WEIGHT IN ADULT MALE**
- **50% OF THE BODY WEIGHT IN ADULT FEMALE**

FACTORS AFFECTING FLUID VARIATIONS

- Physiological
  - Adipose Tissue
  - Sex
  - Age
- Pathological
  - Dehydration
  - Overhydration

- **Measurement of Fluid Volumes in the Different Body Fluid Compartments—The Indicator-Dilution Principle**

- “Indicator-dilution” method of measures the volume of a fluid compartment, which is based on the principle of conservation of mass.

- This means that the total mass of a substance after dispersion in the fluid compartment will be the same as the total mass injected into the compartment.

- If none of the substance leaks out of the compartment, the total mass of substance in the compartment (Volume B \ Conc.B) will equal the total mass of the substance injected (Volume A \ Conc. A).

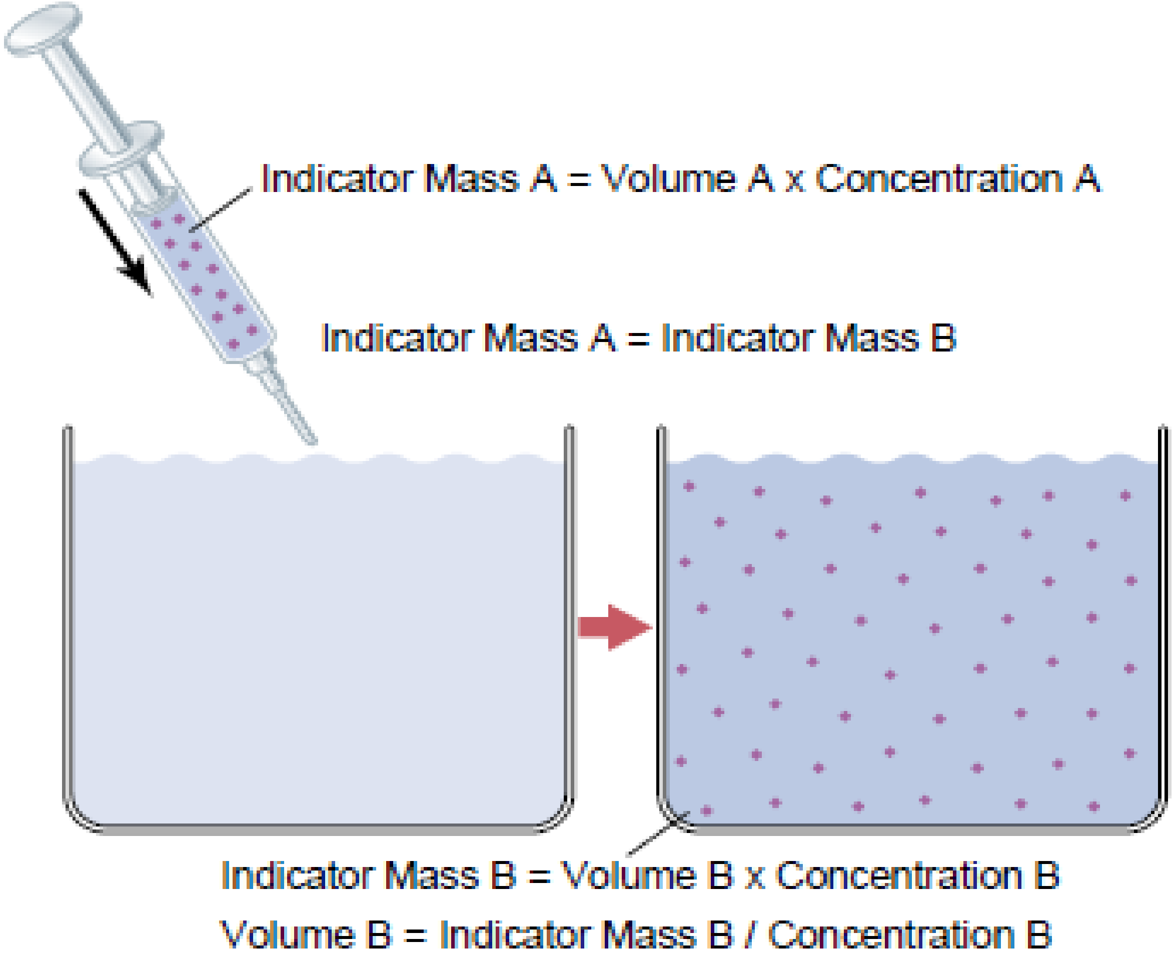


Figure 25–4

Indicator-dilution method for measuring fluid volumes.

$$\text{Volume B} = \frac{\text{Volume A} \times \text{Concentration A}}{\text{Concentration B}}$$

- (1) the total amount of substance injected into the chamber (the numerator of the equation)
  (2) the concentration of the fluid in the chamber after the substance has been dispersed (the denominator).

- For example, if 1 milliliter of a solution containing 10 mg/ml of dye is dispersed into chamber B and the final concentration in the chamber is 0.01 milligram for each milliliter of fluid, the unknown volume of the chamber can be calculated as follows:

$$\text{Volume B} = \frac{1\ \text{ml} \times 10\ \text{mg/ml}}{0.01\ \text{mg/ml}} = 1000\ \text{ml}$$

- This method can be used to measure the volume of virtually any compartment in the body as long as

- (1) the indicator disperses evenly throughout the compartment.

- (2) the indicator disperses only in the compartment that is being measured.

- (3) the indicator is not metabolized or excreted.

Table 25–3

Measurement of Body Fluid Volumes

Volume	Indicators
Total body water	$^{3}H_2O$, $^{2}H_2O$, antipyrine
Extracellular fluid	^{22}Na, ^{125}I-iothalamate, thiosulfate, inulin
Intracellular fluid	(Calculated as Total body water − Extracellular fluid volume)
Plasma volume	^{125}I-albumin, Evans blue dye (T-1824)
Blood volume	^{51}Cr-labeled red blood cells, or calculated as Blood volume = Plasma volume/(1 − Hematocrit)
Interstitial fluid	(Calculated as Extracellular fluid volume − Plasma volume)

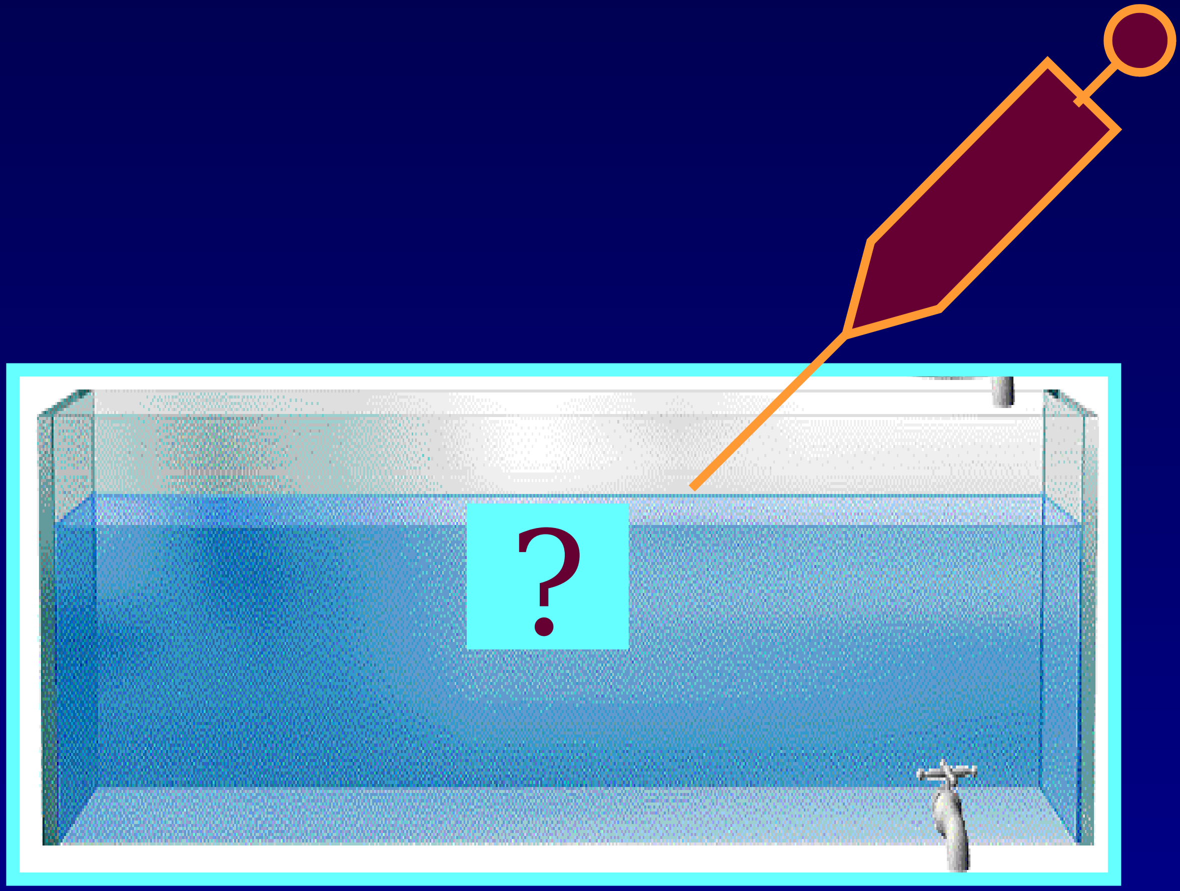
From Guyton AC, Hall JE: Human Physiology and Mechanisms of Disease, 6th ed. Philadelphia: WB Saunders, 1997.

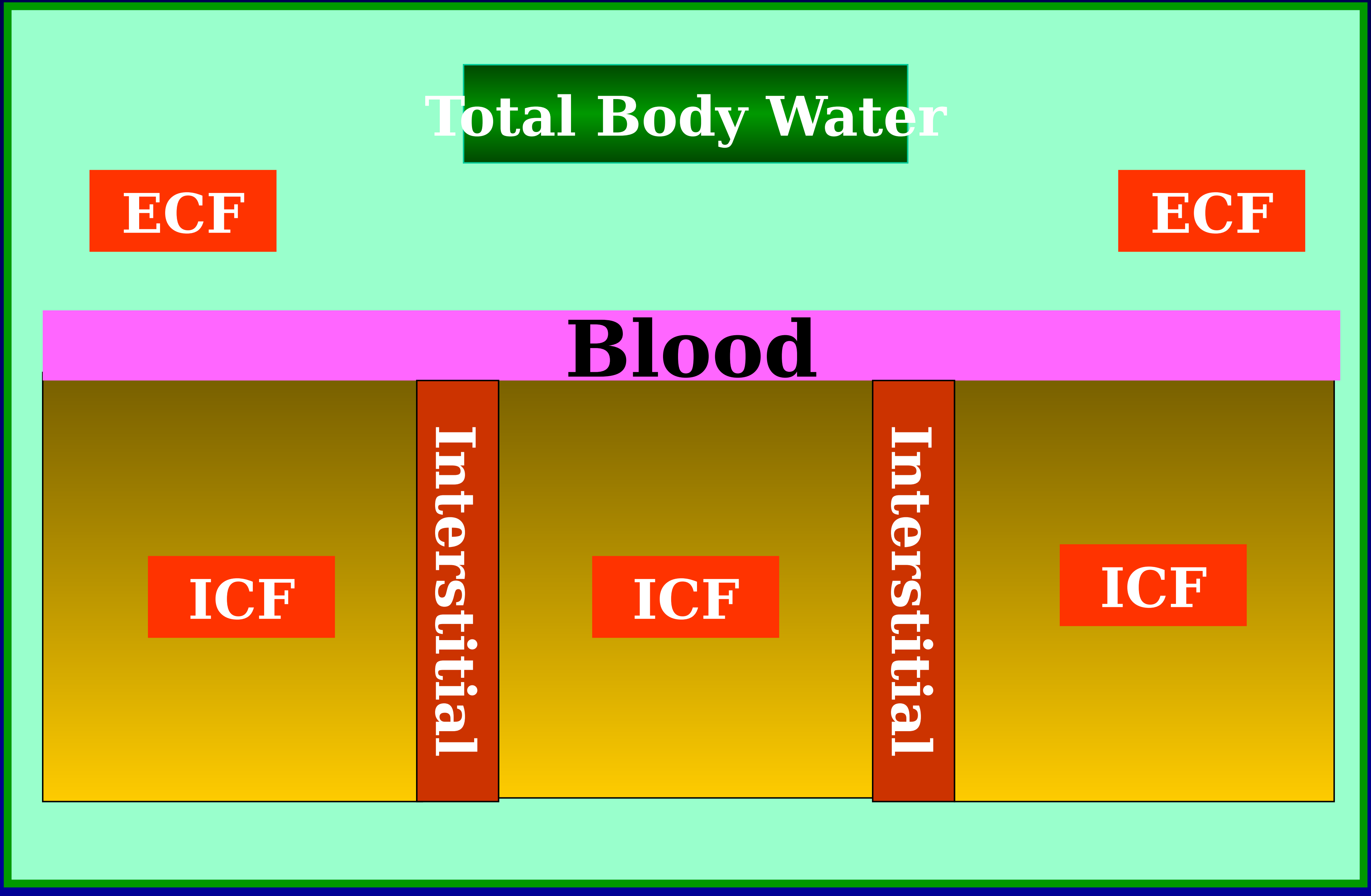
- **Hematocrit (Packed Red Cell Volume).** The **hematocrit is** the fraction of the blood composed of red blood cells, as determined by centrifuging blood in a "hematocrit tube" until the cells become tightly packed in the bottom of the tube.

- In men, the measured hematocrit is normally about 0.40, and in women, it is about 0.36

CRITERIA FOR A SUITABEL DYE.

- MUST MIX EVENLY THROUGHOUT THE COMPARTMET
- NON TOXIC
- MUST HAVE NO EFFECT OF ITS OWN ON THE DISTRIBUTION OF WATER OR OTHER SUBSTANCES IN THE BODY
- NOT METABOLIZED OR EXCRETED.




Total Body Water
ECF
ECF
Blood
Interstitial
Interstitial
ICF
ICF
ICF

VOLUME MEASUREMENT OF VARIOUS FLUIDS COMPARTMETNS

INTERSTITIAL FLUID

ECF – Plasma Volume

INTRACELLULAR FLUID

TBW – ECF

VOLUME MEASUREMENT OF VARIOUS FLUIDS COMPARTMETNS

BLOOD PLASMA.

- **EVAN'S BLUE**
- **RADIOACTIVE LABELED 125 I ALBUMIN**

$$\text{Total blood volume} = \frac{\text{Plasma volume}}{1 - \text{Hematocrit}}$$

For example, if plasma volume is 3 liters and hematocrit is 0.40, total blood volume would be calculated as

$$\frac{3 \text{ liters}}{1 - 0.4} = 5 \text{ liters}$$

Hematocrit (the fraction of the total blood volume composed of cells)

Regulation of Fluid Exchange and Osmotic Equilibrium Between Intracellular and Extracellular Fluid

- In human body a frequent problem in treating seriously ill patients is maintaining adequate fluids in one or both of the intracellular and extracellular compartments.

- The relative amounts of extracellular fluid distributed between the plasma and interstitial spaces are determined mainly by the balance of hydrostatic and colloid osmotic forces across the capillary membranes.

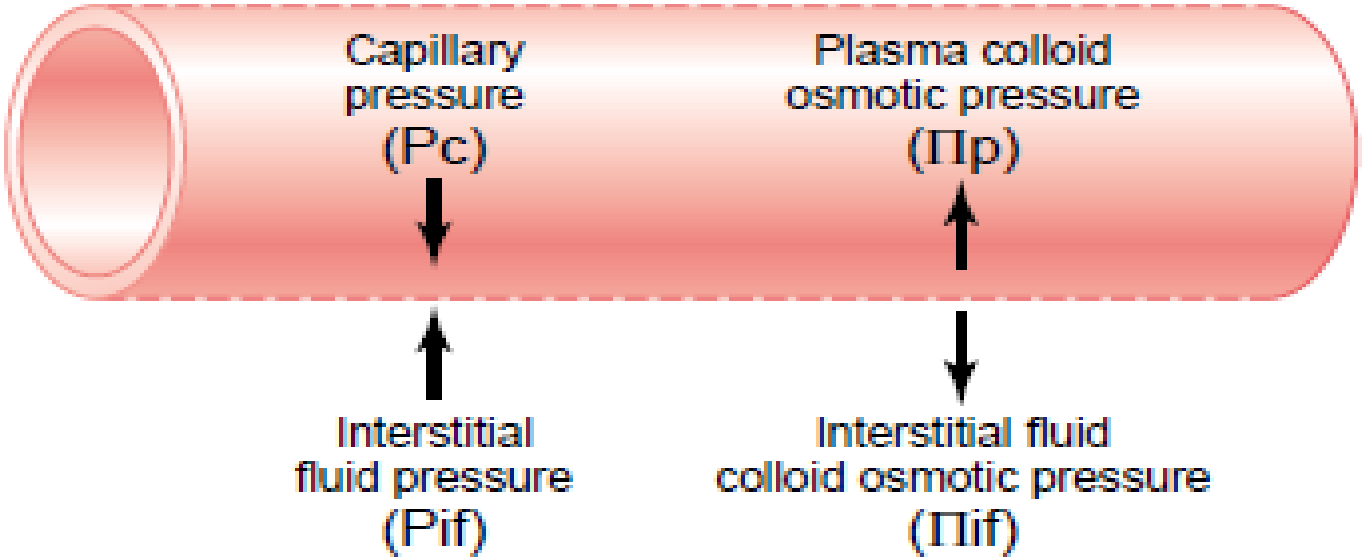


Figure 16–5

Fluid pressure and colloid osmotic pressure forces operate at the capillary membrane, tending to move fluid either outward or inward through the membrane pores.

- Hydrostatic pressure drives fluid out of the capillary (i.e., filtration), and is highest at the arteriolar end of the capillary and lowest at the venular end.

- Colloid osmotic pressure is just the opposite, and it is exerted by the protein albumin.

- Albumin is normally too large to pass through the capillary walls, so it stays inside the capillaries.

- Albumin pulls fluid towards itself. This effect of albumin is colloid osmotic pressure.

- This keeps too much fluid from leaving the capillaries.

- The distribution of fluid between intracellular and extracellular compartments, in contrast, is determined mainly by the osmotic effect of the smaller solutes—especially sodium, chloride, and other electrolytes—acting across the cell membrane

Basic Principles of Osmosis and Osmotic Pressure

- *Osmosis is the net diffusion of water across a selectively permeable membrane from a region of high water concentration(low solute conc.) to one that has a lower water concentration(high solute conc.)*

- Because cell membranes are relatively impermeable to most solutes but highly permeable to water (i.e.selectively permeable), whenever there is a higher concentration of solute on one side of the cell membrane, water diffuses across the membrane toward the region of higher solute concentration.
- If NaCl added to ECF………….?
- If NaCl is removed from

- Total number of particles in a solution is measured in *osmoles.*
  - *One osmole (osm) is equal to 1 mole (mol)*($6.02 \backslash 10^{23}$) of solute particles.
- Therefore
  - a solution containing 1 mole of glucose in each liter has a concentration of 1 osm/L

- If a molecule dissociates into two ions (giving two particles), such as sodium chloride then a solution containing 1 mol/L will have an osmolar concentration of 2 osm/L & VICE VERSA.

- In general, the osmole is too large a unit for expressing osmotic activity of solutes in the body fluids.

- The term *milliosmole (mOsm), which equals 1/1000* osmole, is commonly used.

Osmolality and Osmolarity

- The osmolal concentration of a solution is called *osmolality when the concentration* is expressed as *osmoles per kilogram of water;*

- *it is* called *osmolarity when it is expressed as osmoles per liter of solution.*

- About 80 percent of the total osmolarity of the interstitial fluid and plasma is due to sodium and chloride ions, whereas for intracellular fluid, almost half the osmolarity is due to potassium ions and the remainder is divided among many other intracellular substances

- Total osmolarity of each of the three compartments is about 300 mOsm/L (282mOsm/L), with the plasma being about 1 mOsm/L greater than that of the interstitial and intracellular fluids. The slight difference between plasma and interstitial fluid is caused by the osmotic effects of the plasma proteins

Osmotic Pressure.

- Osmosis of water molecules across a selectively permeable membrane can be opposed by applying a pressure in the direction opposite that of the osmosis.

- The precise amount of pressure required to prevent the osmosis is called the *osmotic pressure.*

- Osmotic pressure, therefore, is an indirect measurement of the water and solute concentrations of a solution.

- The higher the osmotic pressure of a solution, the lower the water concentration and the higher the solute concentration of the solution.

Relation Between Osmotic Pressure and Osmolarity

- The osmotic pressure of a solution is directly proportional to the concentration of osmotically active particles in that solution.

- Size :e.g. glucose & albumin.
- Osmotically active particles: NaCl

- Thus, the osmotic pressure of a solution is proportional to its osmolarity, a measure of the concentration of solute particles.

Table 25–2

Osmolar Substances in Extracellular and Intracellular Fluids

	Plasma (mOsm/L H_2O)	Interstitial (mOsm/L H_2O)	Intracellular (mOsm/L H_2O)
Na^+	142	139	14
K^+	4.2	4.0	140
Ca^{++}	1.3	1.2	0
Mg^+	0.8	0.7	20
Cl^-	108	108	4
HCO_3^-	24	28.3	10
HPO_4^-, $H_2PO_4^-$	2	2	11
SO_4^-	0.5	0.5	1
Phosphocreatine			45
Carnosine			14
Amino acids	2	2	8
Creatine	0.2	0.2	9
Lactate	1.2	1.2	1.5
Adenosine triphosphate			5
Hexose monophosphate			3.7
Glucose	5.6	5.6	
Protein	1.2	0.2	4
Urea	4	4	4
Others	4.8	3.9	10
Total mOsm/L	301.8	300.8	301.2
Corrected osmolar activity (mOsm/L)	282.0	281.0	281.0
Total osmotic pressure at 37°C (mm Hg)	5443	5423	5423

Isotonic, Hypotonic, and Hypertonic Fluids

- If a cell is placed in a solution of impermeant solutes having an osmolarity of 282 mOsm/L, the cells will not shrink or swell because the water concentration in the intracellular and extracellular fluids is equal and the solutes cannot enter or leave the cell. Such a solution is said to be *isotonic because it neither shrinks* nor swells the cells.

- EXAMPLES
- 0.9 per cent solution of sodium chloride
- (0.9percent solution means that there is 0.9 gram of sodium chloride per 100 milliliters of solution, or 9 g/L)
-
- 5 per cent glucose solution.
  - The tonicity of solutions depends on the concentration of impermeant solutes.

- If a cell is placed into a hypotonic solution that has a lower concentration of impermeant solutes (<282 mOsm/L), water will diffuse into the cell, causing it to swell; water will continue to diffuse into the cell, diluting the intracellular fluid while also concentrating the extracellular fluid until both solutions have

- EXAMPLE

- Solutions of NaCl with a concentration of less than 0.9 percent are hypotonic and cause cells to swell

Isosmotic, Hyperosmotic, and Hypoosmotic Fluids.

- Solutions with an osmolarity the same as the cell are called *isosmotic, regardless* of whether the solute can penetrate the cell membrane.

- The terms *hyperosmotic and hypoosmotic refer to* solutions that have a higher or lower osmolarity, respectively, compared with the normal extracellular fluid, without regard for whether the solute permeates the cell membrane.

Effect of Adding Saline Solution to the Extracellular Fluid

- If an *isotonic saline solution is added to the extracellular* fluid compartment, the osmolarity of the extracellular fluid does not change; therefore, no osmosis occurs through the cell membranes.

- The only effect is an increase in extracellular fluid volume.

- If a *hypertonic solution is added to the extracellular* fluid, the extracellular osmolarity increases and causes osmosis of water out of the cells into the extracellular compartment
  - The tonicity of solutions depends on the concentration of impermeant solutes

- The net effect is an increase in extracellular volume (greater than the volume of fluid added), a decrease in intracellular volume, and a rise in osmolarity in both compartments.

- If a *hypotonic solution is added to the extracellular* fluid, the osmolarity of the extracellular fluid decreases and some of the extracellular water diffuses into the cells until the intracellular and extracellular compartments have the same osmolarity.

Glucose and Other Solutions Administered for Nutritive Purposes

- Many types of solutions are administered intravenously to provide nutrition to people who cannot otherwise take adequate amounts of nutrition. Glucose solutions are widely used

- When these solutions are administered, their concentrations of osmotically active substances are usually adjusted nearly to isotonicity, or they are given slowly enough that they do not upset the osmotic equilibrium of the body fluids